

Reducing Ozone

How Much Is It Worth?

In recent years, ozone alerts on hot days have become commonplace in the media. They warn the public in a given area to avoid prolonged outdoor activity and thus limit their exposure to ozone in outdoor air. It has become generally accepted that exposure to high concentrations of ozone can be detrimental to health, particularly in sensitive populations such as children, the elderly, and people with respiratory ailments.

This would imply, naturally, that environmental measures aimed at reducing atmospheric ozone levels would offer concomitant benefits to public health. But environmental policies and expenditures must be justified by clear rationales based upon sound scientific evidence and realistic benefit–cost analysis that acknowledges and quantifies uncertainties. In this month's issue, researchers led by Jonathan I. Levy of the Harvard Center for Risk Analysis selected a sample city—Houston, Texas—to experiment with statistical analysis approaches gleaned from previously published research [*EHP* 109:1215–1226]. They focused on addressing the critical issues and uncertainties involved in performing benefit–cost analyses of reduced ozone concentrations.

To evaluate health outcomes, the authors focused on four factors potentially impacted by exposure to ozone: premature mortality, chronic asthma, respiratory hospital admissions, and minor restricted activity days (those that do not result in work or school loss or bed disability). Interpretation of the relationship between ozone and each health effect is complicated by potential confounding factors, including particulate matter levels and weather. The authors surveyed relevant studies with an eye toward statistical approaches to deal with these confounders, arriving at a quantified estimation of the possible benefits to public health in Houston.

To assign a monetary value to those health benefits, they applied findings from studies that used two competing methods. The “value of statistical life” approach measures the dollar amount an individual is willing to pay to avoid what the authors describe as “a small increase” in mortality risk. The “quality-adjusted life year” approach measures the loss of life expectancy and health quality and is used in medical decision making to compare the cost-effectiveness of different medical interventions. The authors arrived at their conclusions for the Houston case study—that a reasonable estimate of the annual monetary value of reducing ozone concentrations would be between \$0.70 and \$40 per person per $\mu\text{g}/\text{m}^3$ of annual average reduction—by assigning subjective probabilities to values derived using both methods. Because the derived values differed substantially, the uncertainty about the monetary value assigned to mortality contributes significantly to the overall uncertainty in the analysis.

The authors' survey of the existing evidence and their methods for extrapolating conclusions from that body of work showcase the need for further research, which they recommend “should focus on those health outcomes and topics for which reduced uncertainty or different values could lead to different policy options.” —**Ernie Hood**

Lead-Free but Not Problem-Free Human Health Risks from Gasolines

Since 1973, many countries around the world have begun phasing out the use of leaded gasoline in automobiles. The purpose of phasing out leaded gas is to decrease the amount of lead in the atmosphere, thereby eventually decreasing the amount of lead in human blood, which has well-documented adverse effects on health. Unleaded gasolines are largely replacing the leaded formula-

tion, but there is some question as to whether these fuels pose new and different hazards to human health. In this month's issue, a group of Taiwanese researchers led by Hsiao-Hsuan Mi find that certain unleaded gasoline formulations can produce more toxic polycyclic aromatic hydrocarbons (PAHs) than unleaded formulations [*EHP* 109:1285–1290]. The group studied emissions from three types of gasoline in use in the Taiwanese market—premium leaded gasoline (PLG), 92-octane lead-free gasoline (92-LFG), and 95-octane lead-free gasoline (95-LFG).

Many PAHs have been classified as probable or possible carcinogens by the International Agency for Research on Cancer. Since different PAH compounds have different levels of carcinogenic potency, or likelihood of inducing tumor growth, engine exhaust components were analyzed in terms of both their raw PAH content and their potential health risk using a formula based on the carcinogenic potency of the very toxic PAH benzo[*a*]pyrene (BaP).

The toxic equivalency factor—or relative carcinogenic potency—of each of the 21 PAH compounds found in the test emissions was compared to that of BaP.

This yielded a measurement of each compound's BaP equivalent concentration, or BaP_{eq} . PAH and BaP_{eq} concentrations were then summed to arrive at total concentrations for each of the three gasoline formulations. After running tests using the same engine, running speeds (idling, 40 km/hr, 80 km/hr, and 110 km/hr), and sampling and analysis methods, the authors then extrapolated their results to annual consumption figures for the three formulations in Taiwan for the years 1994–1999.

Significant differences were found in the amounts of PAHs and BaP_{eq} concentrations in the exhaust emissions. The 95-LFG contained the highest PAH levels and BaP_{eq} concentrations, followed by the PLG, and then the 92-LFG. As the authors state, logically this would imply that when PLG is replaced with 95-LFG, PAH and BaP_{eq} emissions would increase, whereas when PLG is replaced with 92-LFG, those emissions would decrease.

That conclusion was borne out when the laboratory data were applied to annual Taiwanese consumption rates. During the six-year period examined, PLG consumption dropped substantially, 92-LFG consumption rose steadily, and 95-LFG consumption rose sharply to nearly three times the consumption of the less hazardous



Fair trade-off? Although the removal of lead from gasoline has yielded health benefits, the replacement gasolines offer their own health risks.

92-LFG. The authors' calculations showed that Taiwan's total PAH and BaP_{eq} emission rates consistently increased during the same period. (Whether health effects increased as well was not addressed in this study.)

Although Mi and his colleagues are careful to limit their conclusions to the situation in Taiwan and suggest further studies in other areas with other gasoline formulations, the implication of their work is clear. The threat to human health posed by leaded gasoline may be receding into the past, but the unleaded formulations that have replaced it bring with them new health risks. The good news, however, is that these risks can be mitigated through this type of analysis and appropriate subsequent policy adjustment.

—Ernie Hood

Ripe for an Outbreak

Predicting Ideal Conditions for Ross River Virus

Ross River virus disease (also called epidemic polyarthritides) afflicts thousands of Australians each year with symptoms—joint pain, rash, fever, muscle pain, and fatigue—that may last from several weeks to years. Like West Nile fever and dengue fever, this mosquito-borne disease, the most common of its type in Australia, is on the rise. In recent years, outbreaks have become more common near urban areas, and this reportable disease is significantly impacting industry, agriculture, and tourism, as well as residents in endemic areas.

As more and more arthropod-borne viral diseases spread throughout the world, researchers are striving to improve their ability to predict outbreaks. Now, in a novel and promising approach, researchers at the Centre for Public Health Research at Queensland University of Technology are applying computer modeling techniques borrowed from the fields of economic theory and corporate strategy to study the effects of environmental conditions on disease incidence [EHP 109:1271–1273].

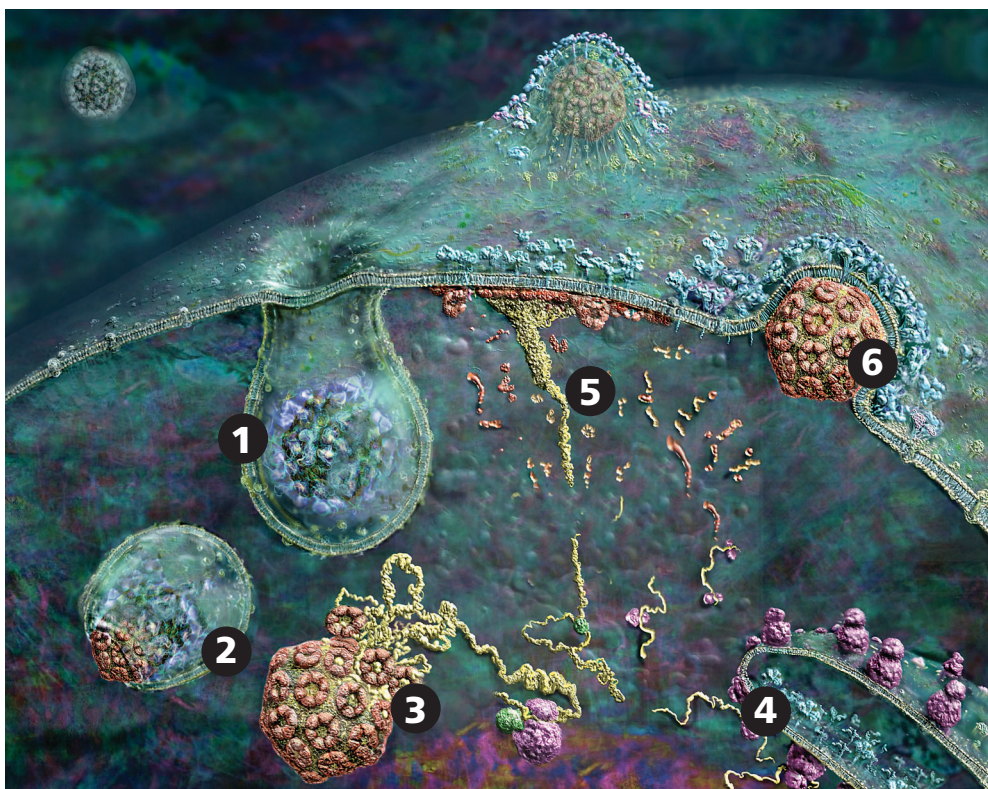
Researchers Shilu Tong and Wenbiao Hu used a time-series methodology called autoregression integrated moving average (ARIMA) modeling to quantify for the first time a clear relationship between climate variation and transmission of Ross River virus in Cairns, Queensland, in Australia's far north tropics. They found that changes in relative humidity and rainfall play significant roles in disease transmission. While the incidence of Ross River virus disease is known to be linked to rainfall, high tide, and temperature—mosquitoes need water to breed and spread—this new modeling reveals the kind of highly specific relationships between climate data and disease incidence that are critical in accurately predicting future outbreaks.

The investigators chose their methodology because ARIMA models are particularly useful in analyzing nonstationary time-series data that contain seasonal trends, such as the pattern of changes in rainfall, humidity, and temperature. They used data from the Australian National Notifiable Diseases Surveillance System, Bureau of Meteorology, and Bureau of Statistics. The model was based on data collected from January 1985 to December 1994, and validated with data from January 1995 through December 1996.

They found a statistically significant association between relative humidity and occurrence of Ross River virus disease five months later, and between rainfall and occurrence of Ross River virus disease two months later. They observed no statistically significant association for temperature, possibly because the temperature in Cairns is usually consistently high.

Tong and Hu suggest that a decrease in relative humidity lessens stream flow, creating stagnant pools that are perfect mosquito-breeding sites. The reduction in water sources also concentrates thirsty wildlife, increasing the potential for disease transmission from insects to vertebrates gathered to drink. Increased rainfall, on the other hand, helps disperse adult mosquitoes.

The investigators observed that many other factors—virus strain, mosquito population densities and survival rates, human behavior, even housing characteristics—need to be incorporated in the modeling. Noting that it is not yet possible to predict the magnitude of changes in disease patterns that global warming will bring, they underscore the need to develop computer models capable of forecasting epidemics under varying environmental conditions. —Laura Alderson



Simplified life cycle of the Ross River virus. 1) The virus lands on a cell surface and is engulfed by the cell membrane. 2) The viral core is released into the cell. 3) Viral RNA is released and instructs the cell to make new viral RNA and protein. 4) New viral surface proteins are made. 5) New viral components collect at the cell membrane. 6) A new virus particle buds from the cell surface.